Claims

1. A method for electrolytic production of aluminium metal from an electrolyte comprising aluminium oxide, by performing electrolysis in an electrolysis cell containing at least one electrolysis chamber with at least one essentially inert anode aligned vertically or vertically inclined and at least one wettable cathode aligned vertically or vertically inclined, and/or at least one bipolar electrode containing both anode and cathode, where the anode evolves oxygen gas and the cathode has aluminium discharged onto it in the electrolysis process, said oxygen gas enforcing an electrolyte flow pattern upward and said produced aluminium flowing downward due to gravity,
c h a r a c t e r i s e d i n that
the temperature of the electrodes are controlled and maintained at a level different from that of the surrounding electrolyte by means of active or passive cooling and/or active and passive heating.

2. A method in accordance with claim 1,
c h a r a c t e r i s e d i n that
the vertically aligned or inclined oxygen-evolving anode is actively cooled by the use of at least one or more heat pipes embedded in and/or connected to the anode and/or the anode stem.

3. A method in accordance with claim 2,
c h a r a c t e r i s e d i n that
the cooling medium in the heat pipes is selected among the elements sodium, potassium, cadmium, caesium, mercury, rubidium, sulphur, iodine, astatine and/or selenium, or from the compounds of heavy metal halides, for instance zirconium fluoride, thallium mono chloride, thallium fluoride, thallium iodide, lead iodide, lead chloride, lead bromide, iron iodide, indium chloride, calcium bromide, cadmium bromide and/or cadmium iodide or aluminium fluoride (pressurised).

4. A method in accordance with claim 1,
characterised in that
the vertically aligned or inclined oxygen-evolving anode is actively cooled by the use of at least one or more flow-channels embedded in and/or connected to the anode and/or the anode stem, said flow-channels carrying and circulating liquid coolants.

5. A method in accordance with claim 4,
characterised in that
said liquid coolants are water, heavy alcohols, oils, synthetic oils, mercury and/or molten salts.

6. A method in accordance with claim 1,
characterised in that
the vertically aligned or inclined oxygen-evolving anode is actively cooled by the use of at least one or more flow-channels embedded in and/or connected to the anode and/or the anode stem, said flow-channels carrying and circulating a gas coolant.

7. A method in accordance with claim 6,
characterised in that
said gas cooling medium is compressed air, nitrogen, argon, helium, carbon dioxide, ammonia and/or other suitable gasses.

8. A method in accordance with claim 1,
characterised in that
the vertically aligned or inclined oxygen-evolving anode is attached to the electrical conductor system through an electric connection, said connection being cooled by means of heat pipes, liquid cooling and/or gas cooling.

9. A method in accordance with claim 8,
characterised in that
said cooling methods are using suitable coolants adapted to the different methods, such as sodium metal for heat pipes, water, heavy alcohols, oils, synthetic oils, mercury and/or molten salts for liquid cooling and/or compressed air, nitrogen, argon, helium, carbon dioxide, ammonia and/or other suitable gasses for gas cooling.

10.A method in accordance with claim 8,
c h a r a c t e r i s e d i n that
said cooling of electrical connection is obtained by using an highly electrical conductive metal with a large cross sectional are, said area being at least 1.1 - 5.0 times the cross sectional area of the anode stem cross sectional area.

11.A method in accordance with claim 1,
c h a r a c t e r i s e d i n that
the vertically aligned or inclined anode has an anode stem between the submerged anode and the electrical connection, said stem having a cross sectional ratio to the anode cross section area of at least 0.005 - 0.5.

12.A method in accordance with claim 1,
c h a r a c t e r i s e d i n that
the vertically aligned or inclined wettable cathode is maintained at a temperature at least at the same level as the electrolyte, preferably slightly higher, said temperature being obtained by use of thermal insulation the cathode stem.

13 A method in accordance with claim 1,
c h a r a c t e r i s e d i n that
the vertically aligned or inclined wettable cathode is maintained at a temperature at least at the same level as the electrolyte, preferably slightly higher, said temperature being obtained by use of electric resistor heating in an intermediate electric current lead between the electrical connection and the cathode stem.

14.A method in accordance with claim 13,
c h a r a c t e r i s e d i n that
said intermediate electric current lead between the electrical connection and the cathode stem is manufactured from dense oxidation resistant graphite, a metal and/or a metal alloy such as stainless steel, Incoloy and/or Hastaloy.

15.A method in accordance with claim 1,

characterised in that

the vertically aligned or inclined wettable cathode is maintained at a temperature at least at the same level as the electrolyte, preferably slightly higher, where the temperature is obtained by reducing the cross sectional area of the submerged cathode compared to the submerged anode area, said cathode area being 0.5 - 1.0 times the cross sectional area of the submerged anode.

16.A method in accordance with claim 15,

characterised in that

the vertically aligned or inclined cathode has a cathode stem between the submerged cathode and the electrical connection, said cathode stem area being 0.005 - 0.5 times the cross sectional area of the submerged cathode.

17.A method in accordance with claim 1,

characterised in that

the vertically aligned or inclined wettable cathode is attached to the electrical conductor system through an electric connection, said connection being cooled by means of liquid cooling and/or gas cooling.

18.A method in accordance with claim 17,

characterised in that

said cooling methods are using suitable coolants adapted to the different methods, such as water, heavy alcohols, oils, synthetic oils, mercury and/or molten salts for liquid cooling and/or compressed air, nitrogen, argon, helium, carbon dioxide, ammonia and/or other suitable gasses for gas cooling.

19.A method in accordance with claim 17,

characterised in that

said cooling of electrical connection is obtained by using an highly electrical conductive metal with a large cross sectional are, said area being at least 1.1 - 5.0 times the cross sectional area of the cathode stem cross sectional area.

20.A method in accordance with claim 1,

c h a r a c t e r i s e d i n that

the vertically aligned or inclined cathode has a cathode stem between the submerged cathode and the electrical connection, said stem having a cross sectional ratio to the cathode of at least 0.005 - 0.05.

21.A method in accordance with claim 1,

c h a r a c t e r i s e d i n that

the vertically aligned or inclined bipolar electrode has an anode surface maintained at a temperature slightly lower than the temperature of the electrolyte and a cathode surface temperature is maintained at a temperature at least at the same level as the electrolyte, preferably slightly higher, said temperatures being obtained by appropriate means of cooling and heating.

22.A method in accordance with claim 21,

c h a r a c t e r i s e d i n that

the anode of the bipolar electrode is cooled by means of heat pipes or flow-channels for liquid and/or gas cooling connected to and/or embedded in the anode.

23.A method in accordance with claim 22,

c h a r a c t e r i s e d i n that

said cooling methods are using suitable coolants adapted to the different methods, such as sodium metal for heat pipes, water, heavy alcohols, oils, synthetic oils, mercury and/or molten salts for liquid cooling and/or compressed air, nitrogen, argon, helium, carbon dioxide, ammonia and/or other suitable gasses for gas cooling.

24.A method in accordance with claim 22,

c h a r a c t e r i s e d i n that

said heat pipes and/or flow-channels for liquid and/or gas cooling are connected to and/or embedded in the anode, preferably in the anode circumference.

25.A method in accordance with claim 21,
characterised in that
the cathode of the bipolar electrode is heated by means of inserting a layer of a material with higher electrical resistively that the cathode material between the cathode and the adjacent anode of the bipolar electrode.

26.A method in accordance with claim 15,
characterised in that
the cathode of the bipolar electrode is heated by means of reducing the active surface area of the cathode so that the bipolar electrode has a cathode to anode surface area ratio of at least 0.5 - 1.0.

27.A method for electrolytic production of aluminium metal from an electrolyte comprising aluminium oxide, by performing electrolysis in an electrolysis cell with horisontal electrode configuration containing at least one essentially inert anode aligned horizontally or slightly horizontally inclined, where the anode evolves oxygen gas and the cathode has aluminium discharged onto it in the electrolysis process, said oxygen gas enforcing an electrolyte flow pattern parallel to the anode surface and said produced aluminium accumulated in an aluminium pool on the cathode surface,
characterised in that
the temperature of the anode is controlled and maintained at a level different from that of the surrounding electrolyte by means of active or passive cooling.

28.A method in accordance with claim 27,
characterised in that
the horizontally aligned or inclined oxygen-evolving anode is actively cooled by the use of at least one or more heat pipes embedded in and/or connected to the anode and/or the anode stem.

29.A method in accordance with claim 28,
characterised in that
the cooling medium in the heat pipes is selected among the elements sodium, potassium, cadmium, caesium, mercury, rubidium, sulphur, iodine, astatine and/or selenium.

30.A method in accordance with claim 27,
characterised in that
the horizontally aligned or inclined oxygen-evolving anode is actively cooled by the use of at least one or more flow-channels embedded in and/or connected to the anode and/or the anode stem, said flow-channels carrying and circulating liquid coolants.

31.A method in accordance with claim 30,
characterised in that
said liquid coolants are water, heavy alcohols, oils, synthetic oils, mercury and/or molten salts.

32.A method in accordance with claim 27,
characterised in that
the horizontally aligned or inclined oxygen-evolving anode is actively cooled by the use of at least one or more flow-channels embedded in and/or connected to the anode and/or the anode stem, said flow-channels carrying and circulating a gas coolant.

33.A method in accordance with claim 32,
characterised in that
said gas cooling medium is compressed air, nitrogen, argon, helium, carbon dioxide, ammonia and/or other suitable gasses.

34.A method in accordance with claim 27,
characterised in that
the horizontally aligned or inclined oxygen-evolving anode is attached to the electrical conductor system through an electric connection, said connection being cooled by means of heat pipes, liquid cooling and/or gas cooling.

35. A method in accordance with claim 34,
c h a r a c t e r i s e d i n that
said cooling methods are using suitable coolants adapted to the different methods, such as sodium metal for heat pipes, water, heavy alcohols, oils, synthetic oils, mercury and/or molten salts for liquid cooling and/or compressed air, nitrogen, argon, helium, carbon dioxide, ammonia and/or other suitable gasses for gas cooling.

36. A method in accordance with claim 34,
c h a r a c t e r i s e d i n that
said cooling of electrical connection is obtained by using an highly electrical conductive metal with a large cross sectional are, said area being at least 1.1 - 5.0 times the cross sectional area of the anode stem cross sectional area.

37. A method in accordance with claim 1,
c h a r a c t e r i s e d i n that
the horizontally aligned or inclined anode has an anode stem between the submerged anode and the electrical connection, said stem having a cross sectional ratio to the anode of at least 0.005 - 0.5

38. An electrowinning cell in accordance with claims 1 and 27,
c h a r a c t e r i s e d i n that
the electrolyte comprises a mixture of sodium fluoride and aluminium fluoride, with possible additional metal fluorides of the group 1 and 2 elements in the periodic table according to the IUPAC system, and the possible components based on alkali or alkaline earth halides up to a fluoride/halide molar ratio of 2.5, and where the NaF/AlF_3 molar ratio is in the range 1 to 4, preferably in the range 1.2 - 2.8.